HELICOPTER

Technical Field

[0001] This application relates to helicopters. The invention has particular application to coaxial rotor helicopters and helicopters in which directional control is accomplished at least in part by shifting a center of gravity relative to a center of lift.

Background

[0002] Current helicopters and other vertical take-off aircraft are extremely complicated and maintenance intensive. As a result, it is often prohibitively expensive to fly helicopters. In practice the use of helicopters is limited to government and commercial operations in which their capabilities are indispensable. Despite their desirable flight characteristics, helicopters are rarely used in general aviation.

[0003] Helicopters have captured human imagination since prior to the first successful airplanes. As a result, there have been a variety of proposed helicopter designs. Many of these proposed designs are impractical. Various patents and published patent applications disclose helicopter designs. These include:

- US patent No. 6,460,482 which discloses a helicopter having two rotors driven coaxially. The rotors can be tilted relative to an airframe of the helicopter.
- US patent No. 5,791,592 which discloses another tilting coaxial rotor helicopter design.
- US patent No. 5,370,341 which discloses an ultra lightweight helicopter having coaxial rotors that a pilot can manoeuver by moving his or her center of gravity.
- US patent No. 5,791,592 which discloses a coaxial rotor helicopter with no tail rotor.
- US patent No. 6,293,492 which discloses a helicopter having coaxial rotors that can be tilted for directional control.
- US patent No. 4,912,999 which discloses a helicopter having a transmission and rotors that can be tilted for directional control.

US patent No. 2,486,059 which discloses a lightweight helicopter having coaxial rotors.

US patent No. 6,182,923 which discloses a helicopter having a rotor and power assembly that is slidable in one direction and pivotal in another.

- US patent application publication No. 20020125368 which discloses an ultralight helicopter having tilting rotors.
- US patent No. 3,722,830 which discloses a helicopter type vehicle having coaxial rotors in which steering is accomplished by shifting a center of gravity of the vehicle.
- PCT patent application publication No. WO02/062661A1 which discloses a lightweight helicopter.

[0004] Despite the wide variety of existing helicopters and proposed helicopter designs, there exists a need for practical helicopters which avoid at least some disadvantages of the prior art. There is a particular need for practical helicopters which are suitable for general aviation use and for practical helicopters having sizes intermediate proposed one-person personal helicopters and larger commercial helicopters.

Summary of the Invention

[0005] This invention has a number of aspects. One aspect of the invention provides a helicopter having a power unit which can be tilted relative to an airframe to provide directional control. The power unit may comprise a pair of coaxial rotors. Another aspect of the invention provides a control system for controllably tilting a helicopter rotor. A still further aspect of the invention provides landing gear assemblies suitable for use in small helicopters.

[0006] In accordance with one embodiment of the invention, a helicopter comprises a power unit having at least one rotor and an engine coupled to drive the rotor. An airframe is suspended from the power unit with a pivotal coupling for pivoting about pitch and roll axes relative to the power unit. A plurality of control actuators are coupled between the airframe and the power unit. The control actuators are adjustable to set pitch and roll angles of the airframe relative to the power unit.

[0007] Preferably, the pitch and roll axes intersect and the plurality of control actuators comprises left and right control actuators which are positioned symmetrically on either side of the roll axis at locations spaced rearwardly from the location at which the pitch and roll axes intersect.

[0008] The airframe may be coupled to the power unit by a support member. The airframe may be pivotally mounted to the support member for rotation about a trim axis parallel to the pitch axis. The helicopter may comprise a trim actuator, connected between the airframe and the support member, which is operable to move the power unit forward and rearward relative to the airframe. The support member may be arch-shaped.

[0009] The control actuators preferably comprise linear hydraulic actuators. Each such linear hydraulic actuator may comprise a cylinder housing having a bore divided into two hydraulic cavities and a piston rod which extends into the bore. The piston rod may comprises a pair of pistons, each of which is located in a corresponding one of the hydraulic cavities, to divide each hydraulic cavity into a pair of volumes.

[0010] A hydraulic controller connected to a source of hydraulic fluid may be provided. The hydraulic controller is preferably connected to supply hydraulic fluid to and remove hydraulic fluid from selected ones of the volumes to controllably move the piston rods relative to their associated cylinder housings. Simultaneous extension or retraction of both control actuators causes pivoting movement of the power unit relative to the airframe about the pitch axis. Simultaneous extension of one control actuator and retraction of the other control actuator causes pivoting movement of the power unit relative to the airframe about the roll axis.

[0011] One or more landing gear assemblies may be provided. Each landing gear assembly preferably comprises a bent tubular member having an upper end attached to the helicopter, a lower end, and a bent portion between the upper and lower ends. The bent portion may have a bore filled with a

plug of a resilient material. Preferably, the landing gear assembly comprises a cross brace coupled between the upper and lower ends of the bent tubular member, wherein the cross brace comprises a first member slidably received in a second member.

[0012] Further aspects of the invention and features of specific embodiments of the invention are described below.

Brief Description of Drawings

[0013] In drawings which illustrate non-limiting embodiments of the invention:

Figure 1 is a perspective view of a helicopter according to a particular embodiment of the invention;

Figure 2 is a right side elevational view of the helicopter of Figure 1;

Figure 3 is a front elevational view of the helicopter of Figure 1;

Figure 4 is a top plan view of a portion of the coupling between the power unit and the airframe of the helicopter taken from the plane 4-4 shown in Figure 3;

Figure 5 is a partially cut away elevational view of a landing gear assembly of the helicopter of Figure 1;

Figure 5A is a sectional view through a portion of the landing gear assembly taken from the plane 5A-5A shown in Figure 5; and,

Figure 6 is a schematic illustration of a hydraulic control system according to the invention.

Description

[0014] Throughout the following description, specific details are set forth in order to provide a more thorough understanding of the invention. However, the invention may be practiced without these particulars. In other instances, well known elements have not been shown or described in detail to avoid unnecessarily obscuring the invention. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

[0015] The preferred embodiments of the invention described herein incorporate a number of symmetric pairs of components. Such pairs of components may be referred to collectively using a single reference character (for example, engines **16**). When referring specifically to an individual one of such pairs of components, the same reference character may be followed by the letter **A** or **B** as the case may be (for example, first engine **16A** and second engine **16B**).

[0016] Figures 1, 2 and 3 show a helicopter **10** according to one embodiment of the invention. In the illustrated embodiment, helicopter **10** is a small personal helicopter capable of carrying a pilot or a pilot plus one passenger. The invention is not limited to such small helicopters. Larger helicopters could also be made to incorporate aspects of the invention. Helicopter **10** has a power unit **12** and an airframe **14**. As will be described in further detail below, airframe **14** is coupled to power unit **12** in a manner which permits power unit **12** to be pivoted relative to airframe **14** about a roll axis **R** and a pitch axis **P** (see Figures 2 and 3).

[0017] Power unit **12** comprises first and second engines **16A**, **16B** (Figures 2 and 3) coupled to drive a pair of counter-rotating rotors **18** which comprise blades **19**. The pitch of blades **19** (i.e. the collective pitch) may be controlled using any suitable mechanism. A number of suitable mechanisms for controlling the collective pitch of helicopter rotor blades are known in the art.

[0018] In the illustrated embodiment, engines **16** are small jet turbine engines. Engines **16** are located symmetrically on either side of rotors **18**. Engines **16** may comprise engines of the type known as auxiliary power units (APUs) or of the type known as ground power units (GPUs) on commercial jet airliners. Such engines may each generate in the range of a few horsepower to over 100 horsepower, for example. APUs and GPUs typically include integrated speed reducing transmissions.

[0019] Engines **16** drive rotors **18** by way of a transmission **20**. In the illustrated embodiment, each engine **16A**, **16B** has an output shaft **21A**, **21B** which carries a corresponding sheave **22A**, **22B**. Transmission **20** has an input shaft **23** which carries a sheave **24** and a clutch **25** (Figure 3). Engine sheaves **22** are coupled to transmission sheave **24** by a plurality of drive belts **26**. Engines **16** drive corresponding magnetos **27**. In the illustrated embodiment, engines **16** also drive a hydraulic pump **28** which is coupled to shaft **23** of transmission **20**.

[0020] A plurality of control actuators **30** are connected between power unit **12** and airframe **14** on either side thereof. In the illustrated embodiment, right and left control actuators **30A**, **30B** are located symmetrically on either side of roll axis **R** at positions spaced behind a location where pitch axis **P** and roll axis **R** cross one another. As explained further below, control actuators **30** can extend or retract to hold airframe **14** at desired angles of pitch and roll relative to power unit **12**.

[0021] In the illustrated embodiment, power unit **12** is coupled to airframe **14** by way of a plate **36** (Figures 2 and 4), a pair of connecting members **38** and an arch support member **41**. As shown best in Figure 4, plate **36** is connected to power unit **12** at pivot joints **35**, which permit power unit **12** to pivot relative to plate **36** about roll axis **R**. As shown best in Figures 2 and 3, connecting members **38** and arch support member **41** are suspended from plate **36** at pivot joints **37**. Pivot joints **37** permit connecting members **38** and arch support member **41** to pivot about pitch axis **P**. Pivot joints **37** are preferably mounted to plate **36** by vibration-suppressing fittings **39**. Pivot joints **35**, **37** preferably comprise bearings.

[0022] Connecting members **38** are rigidly affixed to arch support member **41** which comprises downwardly extending arms **40**. Airframe **14** comprises a main structural member **42** (Figure 1) which is cruciate in shape and is made up of a longitudinally extending support member **44** and transversely extending struts **46**. Preferably, as shown in the illustrated embodiment, transversely extending struts **46** are provided by opposed ends of a tubular

member which extends from one side of helicopter **10** through to the other side. Arms **40** of arch support member **41** are connected to transversely extending struts **46** on either side of airframe **14**. In the illustrated embodiment, arms **40** are pivotally connected to struts **46** and can be pivoted about a trim axis **T** (Figure 3) which is parallel to pitch axis **P**.

[0023] The attitude of airframe **14** can be adjusted relative to arch support member **41** by extending or retracting a trim actuator **48** (Figure 1). Trim actuator **48** may be an actuator similar to those used to control the flaps in some aeroplanes. In general, trim actuator **48** may comprise any suitable linear actuator. For example, trim actuator **48** may comprise a screw jack having a nut which can be driven in rotation about a fixed screw to extend or retract trim actuator **48**, a hydraulic cylinder, a rack and pinion system a ratchet mechanism or the like.

[0024] In the illustrated embodiment, control actuators **30** extend approximately parallel to arms **40** of arch support member **41**. Control actuators **30** and arms **40** provide an approximately parallelogram-shaped linkage. Power unit **12** can be moved forward or rearward relative to airframe **14** by extending or retracting trim actuator **48** and by suitable pivotal motion of arms **40** about trim axis **T**. The forward or rearward movement of power unit **12** by the extension or retraction of trim actuator **48** may be accomplished independently from the extension and/or retraction of control actuators **30**.

[0025] Control actuators **30** may simultaneously and independently control the angle of airframe **14** relative to power unit **12** about both pitch axis **P** and roll axis **R**. The pitch of airframe **14** may be independently adjusted (i.e. without affecting the roll of airframe **14**) by extending or retracting both of control actuators **30A**, **30B** by the same amount. The roll of airframe **14** may be independently adjusted (i.e. without affecting the pitch of airframe **14**) by extending one of control actuators **30A**, **30B** and retracting the other one of control actuators **30B**, **30A**. Combinations of pitch and roll adjustment of

airframe **14** relative to power unit **12** may also be provided by controlled extension and or contraction of control actuators **30A**, **30B**.

[0026] Figure 6 schematically illustrates a construction of a control system **50** for controlling the movement of control actuators **30** according to one embodiment of the invention. Each control actuator **30A**, **30B** comprises a corresponding cylinder housing **52A**, **52B** which slidably receives a piston rod **54A**, **54B**. As shown best in Figures 1 and 2, the distal ends of piston rods **54** connect to power unit **12** and the distal ends of cylinder housings **52** connect to airframe **14**. Piston rods **54** are biased toward a neutral position by centering mechanisms **56**. Figure 6 shows only centering mechanism **56A**, it being understood that control actuator **30B** comprises a centering mechanism having substantially the same components and operating in substantially the same manner as centering mechanism **56A**. In the illustrated embodiment, piston rod **54A** extends through a sleeve **58A**. Block **59A** is slidably disposed on the outside of sleeve **58A** between stops **60**. Block **59A** is connected to piston rod **54A** by pin **61A** which extends through slot **62A**. Centering mechanism **56A** comprises a pair of springs **64A** which are respectively compressed between block **59A** and one of stops **60A**.

[0027] As shown in Figure 6, each cylinder housing **52A**, **52B** has a bore **70A**, **70B** divided into an upper hydraulic cavity **72A**, **72B** and a lower hydraulic cavity **74A**, **74B** by a divider **76A**, **76B**. Each bore **70A**, **70B** is closed by a corresponding plate **78A**, **78B**. Rods **54** pass through apertures in dividers **76** and plates **78**. Pistons **80** and **82** are located respectively in upper cavities **72** and lower cavities **74** and are affixed to rods **54**. Pistons **80** and **82** and dividers **76** divide bore **70A** into four volumes **71A_w**, **71A_x**, **71A_y**, **71A_z** (collectively, volumes **71A**) and divide bore **70B** into four volumes **71B_w**, **71B_x**, **71B_y**, **71B_z** (collectively, volumes **71B**).

[0028] Volumes **71A**, **71B** are filled with a hydraulic fluid such as a suitable grade of hydraulic oil. A hydraulic controller **84** permits the position of rods **54** to be controlled by introducing hydraulic fluid into and removing hydraulic fluid from selected ones of volumes **71A**, **71B**. Hydraulic

controller **84** may comprise a pressure increasing valve. When hydraulic controller **84** is in a neutral configuration, volumes **71A**, **71B** are all connected to a hydraulic fluid reservoir **85**, so that hydraulic fluid can flow freely into or out of each volume **71A_w**, **71A_x**, **71A_y**, **71A_z**, **71B_w**, **71B_x**, **71B_y**, **71B_z**.

[0029] A pump **86** provides pressurized hydraulic fluid to hydraulic controller **84**. Hydraulic controller **84** comprises valves **87_w**, **87_x**, **87_y**, **87_z** (collectively, valves **87**). Valves **87** are connected to volumes **71A**, **71B** through ports **89** as shown in Table I and illustrated schematically in Figure 6.

Table I - Hydraulic Connections

Valve	Volume (control actuator **30A**)	Port (control actuator **30A**)	Volume (control actuator **30R**)	Port (control actuator **30B**)
87_w	**71A_w**	**89A_w**	**71B_w**	**89B_w**
87_x	**71A_x**	**89A_x**	**71B_y**	**89B_y**
87_y	**71A_y**	**89A_y**	**71B_x**	**89B_x**
87_z	**71A_z**	**89A_z**	**71B_z**	**89B_z**

[0030] Table I and Figure 6 show that when hydraulic controller **84** is operated such that pressurized hydraulic fluid is supplied at valve **87_w** and withdrawn at valve **87_z**, then the pressurized hydraulic fluid will flow into volumes **71A_w**, **71B_w** and out of volumes **71A_z**, **71B_z**, so that both piston rods **54** will move upward and both control actuators **30** will extend. The extension of both control actuators **30** causes power unit **12** to pitch forward. During such an operation of hydraulic controller **84**, volumes **71A_x**, **71A_y**, **71B_x**, **71B_y** are connected to reservoir **85**, such that hydraulic fluid will be drawn into volumes **71A_y**, **71B_y** and expelled from volumes **71A_x**, **71B_x** as necessary to allow control actuators **30** to extend. If hydraulic controller **84** is operated so that pressurized hydraulic fluid is supplied at valve **87_z** and withdrawn at valve **87_w**, then the reverse occurs,

causing both piston rods **54** to move downward, both control actuators **30** to retract and power unit **12** to pitch rearward.

[0031] If hydraulic controller **84** is operated so that pressurized hydraulic fluid is supplied at valve **87_x** and withdrawn at valve **87_y**, then, for control actuator **30A**, the pressurized hydraulic fluid will flow into volume **71A_x** and out of volume **71A_y**. However, for control actuator **30B**, the pressurized hydraulic fluid will flow into volume **71B_y** and out of volume **71B_x**. This movement of pressurized hydraulic fluid moves piston rod **54A** downward causing control actuator **30A** to contract, while piston rod **54B** moves upward causing control actuator **30B** to extend. The result is a rightward roll of power unit **12**. During such an operation of hydraulic controller **84**, volumes **71A_w**, **71A_z**, **71B_w**, **71B_z** are connected to reservoir **85**, such that hydraulic fluid can flow into or out of volumes **71A_w**, **71A_z**, **71B_w**, **71B_z** as necessary to allow actuators **30** to extend or retract. If hydraulic controller **84** is operated so that pressurized hydraulic fluid is supplied at valve **87_y** and withdrawn at valve **87_x**, then the reverse occurs and actuator **30A** is extended while actuator **30B** is retracted, resulting in a leftward roll of power unit **12**.

[0032] A joystick **90** (Figures 1 and 2) may be provided to allow a pilot to control the operation of hydraulic controller **84** and to select a desired orientation of power unit **12**. Joystick **90** may be connected directly to operate hydraulic controller **84**. Alternatively, joystick **90** may be connected to hydraulic controller **84** by way of a suitable intermediate system, which may be mechanical, electronic or some combination of mechanical and electronic, for example. In a currently preferred embodiment of the invention, joystick **90** operates valve **84** directly. Pushing joystick **90** forward pitches power unit **12** forward. Pulling joystick **90** rearwardly pitches power unit **12** rearwardly. Pushing joystick **90** to the right rolls power unit **12** to the right and pushing joystick **90** to the left rolls power unit **12** to the left. Pushing joystick **90** in another direction results in moving power unit **12** through some combination of pitch and roll.

[0033] In the illustrated embodiment of the invention, airframe **14** comprises a longitudinally extending support member **44**. Longitudinally extending support member **44** supports a pilot's seat **96** (Figures 1 and 2) and may optionally support a passenger's seat (not shown) located behind seat **96**. Longitudinally extending support member **44** may comprise a beam formed from aluminum or another suitablly strong material having a cross-section which provides sufficient rigidity and is sufficiently light in weight.

[0034] As discussed above, transversely extending struts **46** may comprise ends of a tube **97** which passes through an aperture in longitudinally extending support member **44**. Braces (not shown) may be provided between longitudinally extending support member **44** and transversely extending struts **46** to help maintain the perpendicular orientation of transversely extending struts **46** with respect to longitudinally extending support member **44**. Arms **99** extend rearwardly from transversely extending struts **46** to support lower ends of control actuators **30**.

[0035] A cockpit bubble **100** may be provided. Cockpit bubble **100** provides an enclosed space for a pilot and any passengers of helicopter **10**. Cockpit bubble **100** may be formed from a suitable plastic such as Plexiglass™, for example. At least a front portion of cockpit bubble **100** is transparent. At least the outer ends of transversely extending struts **46** are located outside of cockpit bubble **100**. Connecting members **38**, arch support member **41**, control actuators **30** and power unit **12** are also outside of cockpit bubble **100**. Cockpit bubble **100** may be affixed along longitudinally extending support member **44**.

[0036] Landing gear assemblies **102** are attached to corresponding outer ends of transversely extending struts **46**. Landing gear assemblies **102** are preferably resiliently compressible, so that they may absorb normal shocks which may occur during landing of helicopter **10**. Landing gear assemblies **102** are also preferably deformable in a manner which dissipates energy when they are subjected to greater shocks as might occur, for example, during a crash landing.

[0037] Figure 5 depicts a partially cut-away view of landing gear assembly **102A**. Landing gear assembly **102A** comprises a bent tube **104A**. A lower portion **105A** of tube **104A** provides a landing skid. Tube **104A** has a bend **106A**, which may be reinforced by a reinforcing plug **107A**. Reinforcing plug **107A** may comprise a deformable plastic material such as nylon or the like having a diameter which matches an inner diameter of the bore of tube **104A**. Reinforcing plug **107A** may be introduced into tube **104A** before tube **104A** is bent. Tube **104A** may comprise any suitable material. In one example embodiment, tube **104A** comprises a 6061 T6 aluminum tube which has been annealed in the vicinity of bend **106A**.

[0038] An upper end **108A** of tube **104A** is fastened to transversely extending strut **46A**. In the illustrated embodiment of the invention, upper end **108A** of tube **104A** passes through holes **109A** in the wall of transversely extending strut **46A**. Holes **109A** are preferably located such that the central axis of the upper end **108A** of tube **104A** intersects generally with the central axis of transversely extending strut **46A**. A cross brace **110A** extends between upper and lower portions **108A**, **105A** of tube **104A**. Cross brace **110A** may deform as described below under flexing of tube **104A**.

[0039] In the illustrated embodiment, cross brace **110A** comprises a first member **112A** which is slidably received by a second member **114A**. Members **112A** and **114A** are preferably round tubes. The outer diameter of member **112A** fits slidably into the inner diameter of member **114A**. When tube **104A** is in its unloaded state, members **112A** and **114A** of cross brace **110A** are generally aligned with one another.

[0040] As shown in Figures 5 and 5A, member **114A** may be connected to upper end **108A** of tube **104A** and/or to transversely extending strut **46A**. In the illustrated embodiment, member **114A** passes through holes **118A** in transversely extending strut **46A** and holes **119A** in the upper end **108A** of tube **104A**. Preferably holes **118A** and **119A** are located so that the central axis of member **114A** intersects generally with the central axes of both

transversely extending strut **46A** and the upper end **108A** of tube **104A**. Preferably, tube **104A**, strut **46A** and member **114A** intersect generally perpendicularly..

[0041] As shown in Figure 5A, a bolt **120A** passes through an end cap **122A** on transversely extending strut **46A** and through both tube **104A** and member **114A**. In the illustrated embodiment, bolt **120A** extends axially with respect to transversely extending strut **46A**. A solid plug **123A** fills the bore of member **114A** at the point where bolt **120A** passes through it. A similar plug **124A** fills the bore of tube **104A** where member **114A** and bolt **120A** pass through it. Plugs **123A** and **124A** prevent tube **104A** and member **114A** from being significantly deformed by the pressure exerted by bolt **120A** and also prevent dirt and moisture from entering the bores of tube **104A** and member **114A**. Plugs **123A** and **124A** may be made of any suitable material, such as nylon or aluminum, for example.

[0042] As discussed above, tube **104A** is bent when it is in its unloaded state. If tube **104A** begins to bend to a greater degree, then member **112A** initially slides telescopically into member **114A**. As the amount of bending of tube **104A** increases, members **112A** and **114A** become misaligned. This increases the force required to telescopically slide member **112A** into member **114A** and causes energy to be dissipated. If the amount of bending of tube **104A** increases even further, then member **112A** will either bind in member **114A** or contact the end of plug **123A**. If bending forces continue to be applied to tube **104A**, then either bolt **120** will shear or tube **104** will buckle. Bolt **120A**, tube **104A** and other parts of landing gear assembly **102A** may be designed to progressively dissipate a desired amount of energy as landing gear assembly **102A** collapses under abnormal impacts. Thus, landing gear assembly **102A** provides a structure which progressively absorbs energy as force is applied to lower portion **105A** of tube **104A**.

[0043] Member **112A** may be connected to lower portion **105A** of tube **104A** in any suitable manner. In the illustrated embodiment, member **112A** is coupled to a fitting **128A** which is in turn affixed to lower portion **105A**. As

shown in Figure 1, wheels **130A** may be provided on lower portion **105A** of tube **104A** to facilitate movement of helicopter **10** along the ground.

[0044] Helicopter **10** also includes a similar landing gear assembly **102B** on its opposing side. Landing gear assembly **102B** comprises similar components to landing gear assembly **102A** depicted in Figures 5 and 5A and described above. Such components of landing gear assembly **102B** include: a bent tube having an upper portion and a lower portion; a cross brace having telescopically slidable members; plugs for the tubes and cross brace members; and wheels. The bent tube and cross brace of landing gear assembly **102B** may be mounted to transversely extending strut **46B** in the same manner as landing gear assembly **102A** is mounted to transversely extending strut **46A**. It will be appreciated that the components of landing gear assembly **102B** may function in a manner similar to the components of landing gear assembly **102A** described above.

[0045] It can be seen that landing gear assemblies **102A**, **102B**, arch support **41** and power unit **12** are all connected to one or more of transversely extending struts **46A**, **46B**. Transversely extending struts **46** may comprise a single tube **97** which provides a common connection member for these structures. When helicopter **10** is on the ground, the weight of power unit **12** is supported by arch support member **41** and landing gear assemblies **102**. Advantageously, parts of airframe **14** other than tube **97** do not need to bear the weight of power unit **12**.

[0046] In operation, helicopter **10** can be caused to lift off by increasing the collective pitch of rotors **18** and applying power to engines **16** to turn rotors **18** in counter rotation. Trim actuator **48** may be operated to place the center of gravity of helicopter **10** directly under the lift point of rotors **18** under hover conditions. Helicopter **10** can be caused to rotate to face in a different direction by altering the pitch of one of rotors **18**. Helicopter **10** can be caused to move in a desired direction by tilting power unit **12** in the desired direction as described above.

[0047] During forward flight, the yaw of helicopter **10** can be controlled by adjusting air foil **132** (Figures 1 and 2). Air foil **132** may be operated by foot pedal **133**, for example.

[0048] Those skilled in the art will appreciate that this invention has various aspects which can advantageously be used together. These aspects of the invention can also be used individually. For example, landing gear assemblies **102**, as described above, may be used in any suitably sized helicopter. A hydraulic control system **50** incorporating control actuators **30**, as described above, may be used in contexts other than those described above.

[0049] As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. For example:

- the illustrated embodiment of the invention employs a pair of control actuators **30**. Additional control actuators may be provided;
- the construction of air frame **14** may be varied. For example, longitudinally extending member **44** and transversely extending struts **46** may be replaced with a generally planar horizontal base member;
- joystick **90** may be replaced by other devices for controlling the control actuators of hydraulic control system **50** .

[0050] Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.